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A Progress Report

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BULLETIN NO. 262.

Root-rot of Tobacco in Kentucky and its Control

(A Progress Report)

By W. D. Valleau, Ralph Kenney and E. J. Kinney

Since 1920 studies have been conducted by the Kentucky Experiment Station on the black root-rot of tobacco, caused by the fungus *Thielavia basicola* Zopf., as it occurs in Kentucky. These studies have centered on the relative resistance of the various so-called varieties of Burley tobacco to the disease, the selection of strains of tobacco, especially of the stand-up type, which are resistant to the disease and of high quality, and a study of the distribution of the disease in the State. After the work on Burley was well under way, a study was begun of the relative resistance of the Kentucky dark tobacco varieties to the disease, and of the possibility of developing highly resistant strains of the various types of dark tobacco. As certain phases of the work have been nearly completed, a progress report of the work up to the present time will be given in this bulletin.

DISTRIBUTION OF BLACK ROOT-ROT IN KENTUCKY (1).

Black-root has long been recognized as a serious hindrance to the tobacco industry of Kentucky. Altho growers have not understood the disease, they have recognized the futility of trying to use the same seedbed site two years in succession, and have recognized that tobacco will often fail almost completely if grown too often on the same soil. Thus, as a result of experience, they have gradually developed a system of culture which has tended to reduce the injury from black-root to a point where in some communities the disease is not recognized as a serious factor,

(1) A description of this disease may be found in Kentucky Experiment Station Circular No. 28, 1922.

many growers insisting that they do not have to contend with it. With the rapidly decreasing amount of virgin soil, however, the disease is causing an increasing amount of injury and each year more farmers are recognizing it as a limiting factor in tobacco production on certain pieces of land.

With the introduction of resistant strains of stand-up Burley it has been possible, by comparison of the rates of growth of resistant and susceptible varieties, to make an extensive survey of the distribution of the disease in the Burley section of the State. Preliminary surveys in 1920 and '21, in the vicinity of Lexington, in which records were made of the number of diseased and apparently disease free fields observed, indicated that about 50 per cent of the Burley tobacco crops were definitely injured by black root-rot and that another 10 per cent were so affected that the loss probably would be extensive if the same fields were again set to tobacco. Later and more extensive data indicate that these figures are rather high for the Burley section as a whole.

In 1923 approximately 2,000, and in 1924 approximately 1,200 teaspoon packages of seed of resistant strains of Burley tobacco were distributed to farmers who requested it. Some of them knew that they were having difficulty with black-root, but the majority probably did not know whether they were troubled with the disease or not. This amount of seed was usually sufficient for planting three or four rows of the resistant strain thru a field of the local variety. Thus comparisons of the relative rates of growth of the two types could readily be made. As most of the commonly grown varieties of Burley are quite susceptible to the disease, differences in the rates of growth in favor of the resistant type have in our experience always indicated the presence of the black-root fungus. The results of these trials have been collected by the writers where possible, by county agents and thru questionnaires. Altho the chance for error in data collected in this way is recognized, yet in the striking examples where the local variety made poor growth and the resistant grew normally, it is fairly certain that the difference in growth was due to the presence of the black-root organism in the soil. In 1923, of the reports received of comparative tests of local and resistant strains 840 appeared sufficiently accurate to be used. Of these, 252, or 30 per

ent, reported *striking* differences in growth in favor of the root-ot-resistant strain. These tests were distributed as shown on the map (Fig. 1). The results obtained in 1924, altho less extensive than in 1923, are entirely comparable. Of 142 reports received, 3, or 51.4 per cent, reported that the resistant variety started uicker after setting, and 75 reported more rapid growth of the esistant strain during the summer. The distribution of these ests was similar to those of 1923. Only a comparatively few tests nd observations have been made in the dark tobacco areas, but the ame results probably will be obtained there when a more accurate urvey can be conducted (2).

The results reported indicate a wide distribution of black root-ot in the Burley section of Kentucky, and suggest that sooner or ater the disease is one with which nearly every tobacco grower vill have to contend unless resistant varieties are grown.

THE RELATIVE RESISTANCE OF BURLEY VARIETIES TO BLACK ROOT-ROT

Burley tobacco is supposed to have originated from a few light olored plants found in a dark tobacco variety grown in Brown County, Ohio, in 1864. The cultivation of it spread rapidly thru Central Kentucky and adjoining parts of Ohio and Indiana. At he present time there are several quite distinct types of Burley obacco. Such a variety of types suggests the possibility of a nultiple origin of Burley tobacco from two or more distinct dark obacco varieties. The Kentucky Burleys are for the most part uite susceptible to black root-rot, but we have recently received a strain of Burley from Ontario, Canada, (Routt's Resistant) that s highly resistant and possibly immune to the disease.

The most popular type of Burley now grown in Kentucky is he Stand-up. There are several so-called varieties of Stand-up Burley, all very much alike but possibly differing slightly in cer-ain characters. These as a group are very susceptible to black oot-rot and in a badly diseased field make but poor growth until ate in the summer when growth may be fairly rapid. Of the

(2) An examination by the senior author and County Agent Middle-on of 12 tobacco fields on the Bradshaw pike near Hopkinsville in uly, 1925, showed that seven of them were infected with black root-rot. The injury in some of these fields was severe.

Fig. 1. The figures indicate the number of demonstrations in each county striking enough to indicate the presence of black root-rot in the field. 1923 crop.

and-up types, the varieties known as Kelley, Judy's Pride, Pepr and Vimont Kelley are those most commonly grown. These e all highly susceptible to the disease. A number of other local and-up varieties have been tested, all of which have proved to susceptible except a strain known as Carr. The fact that it as resistant to black-root was not known to Mr. Carr until a test as conducted at the Experiment Station in 1923. It probably riginated from one of the commonly grown stand-up Burley arieties by unconscious selection for disease resistance in a field fected with black-root, as most of the stand-up varieties have occasional plant which is resistant.

There are several slightly different types of drooping leaf Bury called red, twist bud, big silk, etc. For the most part these are ist as susceptible to black-root as the Stand-up Burleys. However, resistant strains of drooping types have been received from everal sources. A variety known as King; another, Green Briar; strain grown by Mr. Gregg near Georgetown; and a strain obained from Mr. J. W. Duncan, Jr., of Nicholasville, have all roved to be resistant. Resistant plants were found in Griffin's road-leaf white Burley, and in a red Burley variety sent to the tation for trial (Fig. 2). Altho the degree of resistance in any f these types is not high, it is sufficient to permit them to make ood growth on badly diseased soil when set after the first of June.

THE DEGREE OF RESISTANCE OF THE RESISTANT BURLEY TOBACCO STRAINS AND OTHER TOBACCO VARIETIES

Resistance of tobacco to the black root-rot fungus probably is lways a relative condition. The term resistance, as it is used in referring to the Kentucky Burley selections, means simply that hese Burley varieties and strains are resistant enough that under he average temperature conditions existing in Kentucky at planting time they will be able to make practically a normal growth, an occasional rootlet only being attacked. The susceptible varieies, on the other hand, are injured when set in diseased soil, altho hey also may make a fair growth under the higher temperature conditions later in the season. Under lower temperature conditions than those existing at setting time in Kentucky the resistant strains of Burley may appear nearly as susceptible as the suscepti-

ble varieties of Burley. Altho highly resistant strains of Burley would be more desirable than these slightly resistant strains, yet because of the fact that these strains are identical in type and quality with the varieties from which they have been selected, and because they are resistant enough to largely eliminate loss from black root-rot, they are filling a very definite need in the tobacco industry of the Burley sections of Kentucky, and probably will continue to do so until highly resistant strains which are as satisfactory in other qualities, can be developed. The relative degree of resistance of the resistant Burleys as compared with other tobaccos grown in Kentucky and with some grown elsewhere, has been determined in several ways.

Plant-Bed Tests. A comparative test of Kentucky resistant strains of Burley with a highly resistant cigar tobacco called Kentucky Yellow, and several varieties of dark tobacco, including One-sucker, Yellow Pryor, Madole, Broadbent and Greenwood, was conducted in 1922, in a diseased plant-bed, placed at one end of a diseased plot. The resistant Burley seed was taken from several strains and thus illustrates rather accurately their resistance as a group. All the varieties made poor growth with the exception of Kentucky Yellow, which appeared to grow normally. The resistant Burleys as a group grew slightly better than the dark tobaccos. All showed extensive root injury with the exception of Kentucky Yellow which appeared to be immune. Later in the season the same varieties were set in the remainder of this plot, taking plants from a steamed bed. Under the higher temperature conditions then prevailing, the resistant Burley strains made nearly equal growth with Kentucky Yellow, the susceptible Burleys grew very slowly and the dark tobaccos made intermediate growth between the susceptible and resistant Burleys.

Greenhouse Plant-Bed Tests. If tobacco seed is sown in the fall in diseased soil in an unheated or partially heated greenhouse, quite accurate determinations of the relative resistance of various strains of tobacco may readily be made. In the falls of 1922 and 1923, tests of this kind were conducted for the purpose of comparing the resistance of a number of strains of dark tobacco with the resistant and susceptible Burleys. In the fall of 1922, thirty-two strains of dark tobacco collected at random in the dark tobacco

Fig. 2. A variety test conducted on badly infected soil on the Experiment Station farm. The five center rows are planted each with two varieties. Those in the foreground are susceptible stand-up varieties, and those in the background are resistant drooping types. On each side are full rows of a resistant stand-up selection (W).

The five center rows are as follows:

1. Pepper and Gregg.
2. Kelley and Twist-Bud (DeLong).
3. Judy's Pride and Griffin's Twist Bud.
4. Vimont Kelley and Duncan.
5. Improved Halley (1923 seed) and Twist Bud (Stafford). Photo July 24, 1924. Original condition of the plants, time and method of setting, and other conditions were as nearly alike as possible thruout this test.

section of the state were compared in this way with Kentucky Y
low, a susceptible Burley, three strains of Kentucky resistant Bu
ley and one of Johnson's Hybrid Burley (3). Kentucky Yello
was most resistant, Johnson's Hybrid Burley next, the Kentuc
selections of Burley next, a strain of one-sucker called Blue Ribb
and a variety called Clarksville appeared nearly as resistant as t
Kentucky resistant selections while the remaining thirty strai
varied down to some that were as susceptible as the susceptib
Burley variety. The general order of resistance was thus th
same as in the diseased plant-bed mentioned above.

The greenhouse test conducted in 1923 gave approximately th
same results as that of the previous year. This test included
strain of Turkish tobacco, the highly resistant strain of Burle
known as Routt's Resistant, received from Mr. D. D. Diggs, o
Harrow, Ontario, Canada, and a number of hybrids of dark an
Burley varieties with resistant forms. Under the greenhouse con
ditions Routt's Resistant and Turkish appeared practically immun
as did also the F_1 hybrids of Turkish, Routt's and Kentucky Ye
low with the susceptible varieties. Two Kentucky Burley selec
tions (W and As. 9) were next in resistance, and the dark to
bacco varieties most susceptible. A susceptible Burley was no
included in this test.

Figure 3 shows quite accurately the results which may b
expected when strains having varying degrees of resistance ar
tested in this way. Number 1 of figure 3 represents Routt'
resistant, a highly resistant strain of Burley of poor quality
2 is a first generation hybrid of 3 (As9, a Kentucky resistan
Burley selection) by Routt's resistant, while 4 and 5 are One
sucker and Yellow Pryor. The relative sizes of the plant
show quite accurately the comparative degree of resistance o
these strains to the black-root organism. Altho the Kentucky
selection, under these conditions, made only slightly bette
growth than the more susceptible varieties, yet the differenc
is significant. It has been found possible in greenhouse plant be
tests to select the very rare resistant plants which appear in such

(3) Johnson, James, Phytopathology 11:p 49, 1921.

Fig. 3. Showing the relative resistance of four strains of tobacco and a hybrid, to black root-rot, under rather low temperatures. Photo, December 19, 1923.

a susceptible variety as Kelley, on the basis of size. In the four attempts made at selection by this means each proved successful the progeny making nearly normal growth in diseased soil in the field, while plants from the original seed proved highly susceptible.

Field Trials. Field trials have been conducted during the past five years, in which the above mentioned varieties, together with other strains and varieties, have been tested. In these tests the same relative degree of resistance has been shown as in the greenhouse tests. In diseased soil the susceptible Burleys make very little growth during the greater part of the summer, the dark tobaccos in an ordinary season are held back for a time and then develop fairly well, but in a season that is unusually cold, as that of 1924, they also make very little growth (Fig. 5). The Kentucky resistant selections have made good growth every season so far, although in 1924 one of them showed signs of injury on black-root soil, but it also made less growth than other varieties on a soil not infected with the black-root organism.

Altho the growth of the Kentucky strains is satisfactory on heavily infected black-root soil, Routt's Resistant, Johnson's Hybrid Burley and Kentucky Yellow all make a slightly more rapid growth indicating some injury to these strains from black-root.

TEMPERATURE RELATIONS OF THE KENTUCKY RESISTANT STRAINS

At the request of Mr. D. D. Diggs, Superintendent of the Harrow, Ontario, Tobacco Experiment Station, two strains of Kentucky resistant Burley were sent him for trial in 1923 and three other strains in 1924. He reported that all five strains showed no resistance whatever as compared with susceptible Burleys. The reason for this appears to be the low temperatures at that station as compared with those in Kentucky. In 1922 the plants were set in the field June 9, at Harrow, and June 3 at Lexington. The average air temperature at Harrow for the month of June was 68.1°F and at Lexington 75.3°F, according to records kept on the Experiment Station farm, the weather bureau reporting 75°F for Lexington. The soil temperature at 3 inches aver-

Fig. 4. Tests of two resistant strains V and W (at sides) in comparison with Judy's Pride and a drooping type (center) of susceptible Burley in diseased soil on the Experiment Station farm in 1922. Photo, July 22, 1922. The temperatures were rather high thru the summer and the susceptible varieties are making fair growth.

ged at Lexington for the same period 73.4°F (23°C) and the alculated average for Harrow was 66.3°F (19°C) a difference f 7.1°F (3.9°C). The range of air temperature at Harrow was rom 45.5°F to 92.5°F, while at Lexington it was from 59°F to 2°F, indicating a much more uniform as well as higher temerature at Lexington than at Harrow during the period following etting. The average temperature at Lexington during the month f June (73.4°F or 23°C) was only 3°C (5.4°F) below the temerature (79°F, or 26°C) which Johnson (4) has shown to be ufficiently high to protect susceptible Burley from all but very ight injury. The susceptible Burleys in diseased soil at Lexngton that year were injured considerably after setting, but by August 22 were two-thirds the size of the resistant Burleys. The verage soil temperatures at Lexington at three inches, during our-week periods following setting, which correspond roughly

(4) Johnson, James, Jour. Agr. Res. XVII: No. 2, 1919.

to June, July and August, were 74.7°F (23.7°C) 78°F (25.5°C) and 78.2°F (25.7°C). The average temperatures the first two weeks after setting at Lexington were slightly lower than those of the four-week period, being 70.4°F (21.4°C) and 73.6°F (23.1°C) respectively. Thus, at temperatures averaging between 21°C and 23°C, (69.8°F and 73.4°F) the susceptible Burleys are injured considerably but at an average temperature of 25.5°C (78°F) they make fair growth (Fig. 4).

These results approximate the results obtained by Johnson using constant temperatures remarkably closely. Under the same conditions the Kentucky resistant strains appear not to be injured at all or only so slightly as not to be noticeable.

Under the same conditions Madole, Little Hill and Greenwood, three Western Kentucky dark tobaccos, made intermediate growth between the susceptible and resistant Burleys. They were definitely injured. Later in the season when plants of these varieties were dug, the only place rotted roots could be found was near the original tap root; the new roots produced during the higher temperatures appearing to be free from injury. The season of 1924 was colder than that of 1922, the Weather Bureau at Lexington reporting 73°F and 73.2°F for the months of June and July, 1924, and 75°F and 76°F for the same two months in 1922. Under these cooler conditions in 1924, susceptible Burley plants in many cases died, while the Western Kentucky dark tobaccos had made only very slight growth by the middle of August (Fig. 5). The Kentucky resistant Burleys grew but slightly slower than the very resistant Burleys. It would seem that the poor development of the dark tobaccos in black-root soil in 1924, was due to the continued cool weather thru July, 73.2°F, the normal temperature for the month being 76.6°F.

The question as to whether temperature conditions low enough to result in extensive injury to the Kentucky resistant strains during the month of June, are likely to be encountered, is an important one to the grower who is relying on these strains for controlling root-rot. Altho the average temperature at which Kentucky resistant Burleys would be seriously injured has not been determined, it lies below an average air temperature of 71°F for

Fig. 5. Showing the relative resistance of a susceptible Burley, a susceptible dark tobacco and a resistant variety in root-rose infested soil. The center row is Kellogg, practically all the plants in the row have been killed by root-rot. A single resistant plant in the center of the row is growing normally. To the left is a row of Cumberland, this represents about the average degree of resistance of Kentucky dark tobaccos to the disease. To the right is a row of Madole x Hare O, back-crosses with Madole. Madole is as susceptible as the Burley. To the right is a row of Madole x Hare O, back-crosses with Madole. Madole is as susceptible as the Burley. To the right is a row of a variety

the month of June, as in 1920 the resistant strain made good growth at this average air temperature. Whether it can be said that the point where extensive injury would occur lies between an average of 71°F and 68°F (the average temperature at which these strains failed at Harrow) can not be stated definitely, as the effect on root-rot of the low night temperatures there as compared with the higher night temperatures at Lexington can not be evaluated properly at present. The mean minimum for June, 1922, at Harrow was 57.3°F while the mean minimum for June in the cooler year of 1920 at Lexington was 63.1°F, a difference of 5.8°; while the difference in mean temperatures for these periods was only 2.9°F. In a 37-year period the mean temperature at Lexington for the month of June has fallen below 71°F only eight times; twice to 70° five times to 69° and once to 68°F. The latter year (1903) the mean minimum temperature fell to 59.3°F (15.2°C) which may be low enough to cause injury to the Kentucky resistant strains. It appears from these figures that there is a possibility of injury to these resistant strains in diseased soil, due to low temperatures, about once in six years. In 1922 when seed of the resistant strains was sowed April 7 in diseased soil the mean temperature for May, when most of the injury probably occurred, was 68.4°F (20.2°C) and the mean minimum for the month was 59.5°F. There was extensive injury to the resistant plants under these conditions in the diseased plant-bed. It will be noticed that these May temperatures are nearly identical with those of the cold June of 1903, when the mean and mean minimum were 68°F and 59.3°F, respectively, indicating that if planting were done at the usual time in such a year a partial failure might occur. Under such abnormal temperature conditions, however, plants probably would be late and thus planting would be delayed until more favorable temperatures prevailed.

DISTRIBUTION AND TESTING OF THE KENTUCKY RESISTANT STRAINS OF BURLEY

In circular 28 (5) a statement was made in regard to the

(5) Strains of stand-up white Burley tobacco resistant to root-rot. Kentucky Experiment Station Circular No. 28, 1922.

election of strains of stand-up Burley resistant to root-rot and lso the results of preliminary tests of some of these strains on Kentucky farms were given. Since that time more extensive tests nave been conducted in order to determine the relative merits of he strains as compared with the commonly grown varieties and ncidentally to gather more extensive data on the distribution of)lack root-rot and the damage caused by it, in the Burley section.

The method used in conducting these tests was to furnish either directly from the Experiment Station or thru county agents or other agencies in the State, level teaspoon samples of seed to anyone wishing to make a comparative test. The small samples were used because they furnished sufficient plants to carry on a reliable trial, usually three or four rows across the field, without a grower risking a large acreage on something with which he was not familiar. Many persons were willing to conduct a trial in this way who would not have done so if a larger planting were required. The method also conserved seed, allowing many more tests to be conducted than if larger samples were distributed. The follow-up work on these tests has not been as extensive as was desired, but has been extensive enough to give a comprehensive idea of the value of the resistant strains. It has consisted of the personal inspection of fields wherever possible during the growing season for the purpose of obtaining records; inspection by county agents during the growing season and after curing; and of questionnaires being sent to growers where personal visits were not made.

Altho several strains have been tested during the progress of the work, the selections from Judy's Pride have received most attention. These are all similar. Some of the Vimont Kelley selections also, have been tested but less extensively. The degree of resistance to black-root seems about the same in both. The quality apparently is better in the Judy's Pride selections. In compiling results for this report, distinction has not been made between the different strains.

1922 Tests. In 1922, three hundred and eleven packets of resistant seed were distributed, primarily thru county agents, in twenty-six counties scattered over the Burley section of the State. Visits were made to 106 of the farms and records obtained on

80 crops, where direct comparison was made between the resistant and the local variety. Fifteen other records were obtained by mail. The resistant tobacco was grown in comparison with 21 so-called varieties of Burley. Fifty-nine comparisons were with stand-up types, 19 with drooping types and the types of the remainder were not recorded.

Of the fields inspected 29, or 32.6 per cent, were definitely infected with black-root, 28 appeared not to be infected and 32 were questionable. On 42 farms, or 47 per cent, the resistant tobacco made more rapid growth and ripened earlier than the local sort. This is fairly good evidence that black-root was present in each of these fields. On 42 farms the rate of growth of the resistant and local variety was identical, and on five farms the local variety grew faster. Forty-three of the growers liked the resistant tobacco best, eight were partial to their own type and the remainder had not yet determined their preferences when the records were obtained.

The records on quality after stripping were less extensive. Mr. H. F. McKenney, then county agent in Fleming County, reported that the quality was as good as that of the local variety, or better, in 20 of 21 tests, while in one test Kelley was considered better. In two counties, Marion and Breckenridge, tobacco grading demonstrations were being conducted co-operatively by the Burley Tobacco Growers' Co-operative Association and the Extension Division of the College of Agriculture. In both counties the official graders of the Co-operative Association compared crops of the resistant tobacco with those of the local varieties, and in all cases pronounced the quality of the resistant crops inspected to be satisfactory.

1923 Tests. In 1923, 1,985 teaspoon samples of resistant seed were distributed for testing, in 67 counties of Kentucky. Thru personal visits made to over 82 farms, thru the efforts of County Agents and thru two sets of questionnaires sent to the demonstrators, a total of 840 individual records were obtained which seemed worthy of tabulation. Tests were conducted in direct comparison with 28 so-called varieties, the majority being with Kelley (295) Judy's Pride (151) and Pepper (45).

Records on the relative rates of growth of two varieties grow-

ng side by side are probably fairly accurate even tho obtained largely by the questionnaire method. Of the 840 records obtained, 242 or 28.8 per cent indicated a very striking difference in the rate of growth between the local and the resistant strain, in favor of the resistant plants.

In these cases the answers to the questions, "Which made the most pounds per acre?" and "How much more do you think it made?" usually were emphasized by such statements as "one-third more," "250 pounds more," "Resistant out-grew mine in same field," "Resistant one-third to one-half larger," "More than twice," "Resistant plants grew much faster," "25 per cent more," etc., leaving little doubt that root-rot was present and that the resistant strain was proving its superiority under these conditions. These cases were distributed rather evenly over the Burley section. Of the 840 answers tabulated, on the relative rates of growth of the resistant and the local strains, 310, or 36.9 per cent stated that the growth was equal; 367, or 43.7 per cent stated that the growth of the resistant plants was superior to that of the local variety, while 163 or 19.4 per cent, stated that the growth of the local variety was superior to that of the resistant. Of these 163 cases, Kelley was reported superior in 36 cases, Judy's Pride in 27 cases, Twistbud in 15 and Red Burley 19, the remaining 66 cases being miscellaneous and unamed varieties. In the cases of the heavier types such as Twistbud and Red Burley there may have been no superiority in growth but merely heavier weight due to a heavier type of tobacco. In cases where Kelley and Judy's Pride were reported as superior, some of the cases may have little significance, due to error in judgment, but certainly in some cases these varieties have proved themselves definitely superior to at least one of the resistant strains under certain soil conditions. These cases will be considered later under brown root-rot.

Taking up the commonly grown varieties separately, in comparison with the resistant; Kelly and the resistant were considered to have made equal growth in 122 cases, the resistant better growth in 137 cases and poorer in 36 cases. Judy's Pride and the resistant made equal growth in 62 cases, the resistant was superior in 62 cases, and Judy's Pride superior in 27 cases. Pepper and the resistant were equal 30 times; the resistant superior 14 times

and Pepper once. Of the heavier types, Twistbud and resistant were equal three times, resistant superior 12 times and the resistant inferior 15 times. Red Burley and resistant were reported the same in 10 instances, the resistant superior in eight and Red Burley superior 19 times. The remaining varieties and the miscellaneous group taken together made equal growth with the resistant 83 times, resistant was superior 132 times and the local variety was superior 64 times. Summarizing the above results it may be stated that 37 times out of 100 equally good results may be expected by growing the resistant as the commonly grown local varieties, and that 19 times out of 100 heavier yields may be expected from the local strains. While 44 times out of 100 better results may be obtained as far as growth is concerned by using the resistant stand-up strains. Altho the local varieties have been reported to have outgrown the resistant in several cases, yet in our observations the differences in rates of growth, with a few exceptions, have not been striking, but where the resistant strains have outgrown the local type the differences due to black root-rot are often very marked.

Quality of the Resistant Tobacco in the 1923 Tests. In March, 1924, questionnaires were sent out to co-operators in an attempt to obtain opinion as to quality, ease of grading and the variety which would be grown the following year. Over 500 records were obtained, most of which could be tabulated for some of the questions. Of 439 expressions of opinion as to relative quality of the local variety and resistant strain, 80 could see no difference, 296 considered the resistant the better quality, and 63 considered the local variety the best.

The quality of Kelley, Judy's Pride and Pepper were considered the same as that of the resistant in 39, 11 and 5 cases respectively; the resistant was considered better than these varieties in 91, 54 and 11 cases respectively, and these varieties were considered better than the resistant in 23, 9 and 5 cases respectively. In 43 comparisons of Red Burley and Twistbud, they were considered as good as the resistant in six cases, better in four cases; and the resistant was considered best in 33 cases. Of 148 comparisons of miscellaneous varieties, these were con-

idered equal in quality to the resistant in 19 cases, better in 2 cases and the resistant better in 107 cases.

Ease of grading is dependent to quite an extent upon uniformity of growth in the field, resulting in a uniform time of topping and a uniform plant size, and on uniformity of type of plant. As the strains tested in 1923 had each been selected from single plants for four consecutive years, the results on ease of grading are of interest in comparison with varieties that usually contain several types of plants. Of a total of 407 expressions in regard to relative ease of grading, 89 could see no difference between their own tobacco and the resistant, 40 considered their own easier to grade and 278 claimed to have found the resistant tobacco easier to grade.

In answer to the question as to what they would grow in 1924, 108 of 364 planned on growing their own variety, 117 expected to grow both their own and the resistant, and 139 or 38 per cent planned on putting their entire crop into the resistant strain.

1924 Tests. In 1924, nearly 1,200 samples of resistant seed were distributed for comparative tests. No attempt was made to visit many of these demonstrations. Questionnaires were sent out in August to obtain information on the relative rate of growth, time of maturity, adaptation of the resistant to the particular conditions, and the variety which would be grown the following year. One hundred and sixty of the answers to the questionnaires received, were considered worthy of tabulation. Eighteen of these growers were growing only the resistant tobacco, while 142 had a direct comparison with another variety. In answer to the question ,"Which variety started the quickest after setting?" 34 could see no difference, in eight cases the local variety, and in 73 cases the resistant was reported to have started first. In severe cases of root-rot the susceptible plants often die. In answer to the question, "Which required most re-setting?" 37 could see no difference, in eight cases the resistant, and in 55 cases the local variety required most re-setting.

As to rate of growth during the summer, 24 reported the two varieties the same, nine that the resistant was slowest, and 75 that the resistant grew more quickly. Twenty-four reported

that both matured at the same time, 12 that the local variety matured first, and 65 that the resistant matured first. Twelve could see no difference in adaptation of the two varieties tested to their soil, 19 considered their own variety best adapted, while 66 considered the resistant best adapted. Fifteen planned on growing their own variety the following year, 19 planned on trying both and 69 considered growing only the resistant in 1925.

SEEDSMEN

Following the preliminary tests of the resistant strains, several seedsmen began raising the resistant seed in quantities for sale. Altho there have been some accidents and susceptible seed has been sold or given away as resistant, the seedsmen who are handling the resistant seed appear now to be using every precaution to safeguard this seed from mixtures. Altho the Kentucky Experimental Station has no direct supervision over the production of resistant seed by private growers, the seedsmen have for the most part shown a desire to co-operate in keeping strains pure. In several cases seedsmen are being supplied each year with sufficient seed from the Experiment Station to plant their seed crop, and thus be more certain of the product. In other cases tests have been conducted during the winter to determine whether seed to be sold was resistant or not, while one seedsman brings plants from his bed from which he will raise his seed crop and tests them in diseased soil at the Experiment Station to make certain of resistance.

BROWN ROOT-ROT OF TOBACCO

Altho black root-rot is very common thruout the Burley section of Kentucky and probably also in the dark section, it is not the only cause of irregular stands of tobacco and of severe stunting in certain fields. A condition quite similar to black root-rot but differing from it in that the roots usually are a brown dead color or sometimes pinkish instead of coal black, as in the case of black root-rot, is quite prevalent. This disease, known in some tobacco areas as brown root-rot, may occur in fields where tobacco has never been grown before, even

tho healthy plants are used. In the most severe cases it appears to be associated with low available fertility, often occurring when tobacco is set in old pastures which have been grazed heavily, altho it has been observed in fields of high fertility. In contrast, black root-rot is notoriously a disease of fertile fields high in organic matter. Brown root-rot may be quite severe after corn, and has caused considerable injury on the Experiment Station Farm in a rotation of alfalfa, corn, tobacco and wheat. Several species of Fusaria and a fungus tentatively identified by Dr. C. L. Shear as *Staganospora arundinis* or as a species of Hendersonia have been isolated from the small rotting rootlets in about equal numbers. So far is has not been possible to demonstrate that any of these organisms are certainly the cause of the trouble, altho several of the species of Fusaria have proved to be injurious to plants growing in test-tubes of agar and also in some instances slightly injurious to plants growing in soil. *Staganospora arundinis* is also slightly injurious to tobacco plants growing in test-tubes of agar. One instance has been seen in which tobacco followed about ten years of continuous corn. The tobacco in this field was injured severely by the disease, making practically no growth until late in the summer. A portion of the same field was set with several varieties of tobacco the following year, but as far as could be determined the disease was not present, or at least only in such small amounts as to be negligible. In preliminary tests a disease entirely similar to brown root-rot has been produced on tobacco by introducing into sand cultures of tobacco (6) dead corn roots collected during the winter from a continuous corn plot.

In 1924, possibly because of the prolonged cool period, this type of injury was very prevalent in Kentucky. The plants in a large percentage of fields in certain of the poorer areas in the State had made very little growth by the middle of August. In more fertile fields, altho there might be considerable injury, it was more difficult to detect.

(6) Unpublished data obtained by Mr. P. E. Karraker and the senior author. Microscopic studies of rotting corn roots, and tobacco roots apparently affected with brown root-rot, growing in sand cultures in the greenhouse have constantly revealed the presence of a phycomycetous fungus at the rotting borders, and behind in the decayed tissue numerous oospores of the pythium type.

One of the black-root resistant strains of tobacco which has been tested quite widely appears to be more susceptible to brown root-rot than the other resistant strains and the commonly grown varieties. This fact undoubtedly explains why in some cases these resistant plants have made inferior growth when compared with the local varieties. A quite striking example of the apparent susceptibility of this strain (W) as compared with other varieties appeared on corn land on the Experiment Station Farm in 1924 (Fig. 6).

It is doubtful whether much progress will be made in combating this disease by plant selection from our commonly grown varieties altho the example given indicates possibilities along this line. Of the nine varieties grown in this field (each repeated four times) the other eight made approximately equal growth and the plants in the rows were quite uniform in size, giving no suggestion that any of the eight varieties contained superior strains. Two of these eight were black-root resistant strains, showing that resistance to black root-rot is not correlated with susceptibility to brown root-rot as might be suggested by the one resistant strain which was more susceptible to brown root-rot. Until more is known in regard to the nature of the brown root-rot, no specific recommendations can be made for its control other than the selection of fields known to be high in available fertility.

Fig. 6. Brown root-rot following corn. On the left is Vimont Kelley only slightly affected, while on the right is an apparently more susceptible strain of tobacco (W) as shown by the small size of the plants thru the entire row. The roots of most of these plants were considerably rotted. Photo, July 24, 1924.

CONCLUSIONS

1. The results of a study of the distribution of black root-rot of tobacco in the Burley section of the State and of the relative resistance of the so-called varieties and selected strains of Burley to the causal organism (*Thielavia basicola* Zopf) are presented.

2. Survey studies carried on over a period of five years, based on observations of random fields and on comparative rates of growth of re-

sistant and susceptible strains of tobacco indicate that black root-rot is causing extensive injury in 30 per cent of the fields set to tobacco each year and a less amount of injury in another 10 to 20 per cent.

3. The commonly grown varieties of the stand-up and drooping Burleys are highly susceptible to black-root but resistant strains of both these types have been found.

4. The resistant Burley selections are not highly resistant to the disease, but are sufficiently resistant that in heavily infested soils they usually make nearly normal growth under the temperature conditions existing at setting time in Kentucky. They are less resistant than the cigar tobacco variety Kentucky Yellow, and more resistant than the Kentucky dark tobacco varieties. In a diseased plant bed or under the lower temperatures farther north (Harrow, Ontario, Canada) the Kentucky selections show no resistance.

5. In extensive field trials, the Kentucky resistant selections have proved superior to the commonly grown varieties on diseased soil both in rate of growth and quality. On disease-free soil the growth of the resistant strains is usually equal to that of the local varieties, but the quality on an average is slightly higher than the local varieties due to more uniformity of type. Planting of resistant strains has reduced the amount of re-setting necessary in diseased fields.

6. Black root-rot is not the only cause of irregular stands of tobacco. A disease known as brown root-rot, the cause of which is not certainly known, may have much the same effect as black root-rot.

7. It is recommended that growers test a resistant strain of tobacco in comparison with their own strain to determine whether or not their soil is infected with black-root. Losses of 200 or 300 pounds of tobacco per acre often occur which would be hard to detect unless a comparative test were conducted. Several distinct types of resistant Burley tobacco have been developed so that the resistant types as a group should not be condemned as a result of a single unsatisfactory test.

NOTE:—Since this bulletin was written, Miss McCormick has published the results of her work on "Perithecia of *Thielavia basicola* Zopf in culture and the stimulation of their production by extracts from other fungi" (Conn. Agr. Exp. Sta. Bul. 269) in which she has apparently shown that cultures from ascospores of *Thielavia basicola* are distinct from chlamydospore cultures and that the latter organism which is the cause of black root-rot of tobacco should properly be called *Thielaviopsis basicola* (Berk) Ferraris.